INTELLECTUAL ABILITIES AND PROTEIN-ENERGY MALNUTRITION: ACUTE MALNUTRITION VS. CHRONIC UNDERNUTRITION

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INTRODUCTION

The question whether energy-protein malnutrition during early childhood has a lasting influence on intellectual abilities carries grave social implications. Despite increasing evidence of such a relationship, many reviewers are hesitant to draw definite conclusions about the damage caused by childhood malnutrition. Warren in 1973 still regarded the "influence of malnutrition on mental development ... a rather open question" (25) and one conclusion after a high-powered symposium in 1974 was that "despite the widely held and widely publicized opinion that malnutrition in early life jeopardizes mental development the evidence to support this opinion -- especially from studies in man -- is scanty" (29). The reasons for this hesitancy are several.

The findings from animal studies are not easily generalized to man because of the extreme conditions to which laboratory animals often are exposed and because the development of the human brain in relation to birth is different from that in most animals. Studies of the relation between energy-protein malnutrition and intellectual abilities in humans are bedevilled by problems of design and measurement, both of nutritional status and intellectual abilities. All investigations -- whether they are called follow-up, longitudinal or intervention studies -- have inherent weaknesses of design. Although many of the studies have been carried out in countries of the developing world, the problems of measuring intellectual abilities among these populations have often received little attention.

There has also been relatively little effort to investigate the role of different aspects of malnutrition. Energy-protein malnutrition of early childhood is a complex of elements, the most important of which pertain to severity, duration and the nature of metabolic disturbances. The forms of energy-protein malnutrition may be subclinical or overt; acute, chronic or relapsing; oedematous (hypoproteinaemic) or marasmic. Children suffer from malnutrition at different ages, and the food deficit often coincides with infections or other nutritional deficiencies. Many of these aspects are interrelated. In the typical case, malnutrition starts during the first year of life, with growth faltering because of an insufficiency of calories and protein. As this condition continues, the child becomes increasingly marasmic. At any time a variety of acute stresses, including infections and further reduction in intake of proteins and calories, may precipitate an acute metabolic imbalance in the child and result in kwashiorkor. One can therefore distinguish in any severely affected child a mixture of chronic undernutrition and acute malnutrition. The first is mainly reflected in stunting of somatic growth, the second in metabolic abnormalities, the chief of which are hypoproteinaemia and oedema. That a distinction should be drawn between undernutrition persisting over time and an acute condition arising over a short period has also been suggested by Waterlow and Rutishauser (26). Others regard acute malnutrition as a metabolic imbalance superimposed on long-term growth failure (20). Clearly energy-protein malnutrition cannot be regarded as a single entity, and it is to some of the distinctions outlined above that the present study addresses itself, notably the age at which children suffer from malnutrition and the differential effects of acute malnutrition and chronic undernutrition.

The present study was carried out in Uganda between 1970 and 1971. From 1953 to 1973 the British Medical Research Council operated a child nutrition research unit in Kampala. Most of the acutely malnourished children admitted to this unit were first seen and thereafter followed in a rural clinic some 12 miles north of Kampala. Many healthy children were also regularly seen at this rural clinic. The records of both groups of children were carefully kept throughout their attendance and offered the opportunity to investigate:

1. the existence of a long-term effect of malnutrition on (a) physical, (b) mental, and (c) motor development; and if so,
2. the influence of the age at which malnutrition occurs;
3. the influence of the type and severity of the malnutrition; and
4. the nature of the effect.

This paper will concentrate on the questions raised under (1b), (2) and (3).

METHOD

Design of Study

Three groups of 20 children (the index children), admitted to the Kampala unit because of energy-protein malnutrition at least 10 years earlier, were selected for this follow-up study. Their ages on admission to the Unit fell between 8 and 15 months (group 1), 16 and 21 months (group 2), and 22 and 27 months (group 3). A comparison group of 20 children (group 4) who had not suffered from clinical malnutrition in infancy was selected from those attending the rural clinic. A design (6) was used in which the children constituting the four groups of children were individually matched. Only Baganda children were included.

Table 1. Study design: sample characteristics, education and socio-economic variables (means and standard deviations in parentheses).*

Group Number / Variable	1 Age 8-15 months	2 Age 16-21 months	3 Age 22-27 months	4 Comparison Group
Child's age at testing (years)	14.1 (1.3)	14.0 (1.5)	13.8 (1.4)	13.9 (1.5)
Child's education (years)	4.6 (1.6)	4.5 (1.3)	4.4 (1.2)	4.4 (1.4)
Male guardian's education (years)	3.1 (3.3)	5.4 (2.5)	4.9 (3.3)	5.7 (3.0)
Female guardian's education (years)	3.2 (2.8)	3.6 (2.5)	1.4 (2.3)	3.5 (2.1)
Socio-economic status: modern expenditures	3.6 (2.2)	2.6 (1.2)	2.3 (1.7)	2.7 (2.4)
Traditional sources	2.7 (1.7)	2.2 (0.9)	1.8 (1.1)	1.9 (1.6)

*Each group includes 20 children: 11 boys and 9 girls.

The Baganda are the largest tribe in Uganda numbering about one million people. They speak Luganda and live in the province of Buganda, where the capital of the country, Kampala, is situated. The children were matched for age, sex, education and social environment. Social environment took into account education of the parents and various household characteristics combined into Guttman scales for modern expenditures and for traditional resources, respectively. The results of the matching are presented in Table 1.

The sex composition of the groups is identical as are, for all practical purposes, the average age and education of the children. Although there are some differences in the environmental variables, they do not consistently favour one group.

The ages of the children at the time of the study ranged from 11 to 17 years. The index children had suffered from acute malnutrition 10 to 16 years previously. Each child's date of birth was checked against the village birth registers when necessary and a child was excluded from the study if there was any doubt or discrepancy about the date of birth. Children with any indication of possible brain insult (such as convulsions or respiratory infections with anoxia) were also excluded, as were those with long-term chronic infections such as tuberculosis. Severe anaemia did not exclude a child unless there was a record of a disturbance of consciousness or convulsions.

Status of the Malnourished Children upon Admission (1954-1961)

The admission records contained data about the type and severity of the symptoms of malnutrition in the index children. From these data seven indicators of the condition of each child at admission were selected.

Many children lost some weight immediately after admission, mainly as a result of loss of oedema fluid. This initial weight loss was expressed as a percentage of the weight on admission. The weight recorded on admission was expressed as a percentage of the expected weight-for-age of each child, using Baganda standards. The lowest haemoglobin level on admission and the serum protein level on admission were recorded. Oedema and over-all clinical severity was rated from 1 to 5 (severe), and skin changes were rated from 1 to 4 (severe) by the attendant doctor at the time of admission (Table 2).

After being admitted to the ward, the children lost an average of 8.4% of their weight. The lowest weight, on the average, was 70% of the Baganda standard; none was above 90%, and only seven children remained above 80% of this standard. The comparison children, whose weights had not fallen below the Boston 10th percentile, remained well above 90% of the Baganda standard throughout the period of observation.

Serum protein levels of the index children averaged 4.2 g/ 100 ml, considerably below normal values. Haemoglobin levels on admission were also low, the average being 6.7 g/100ml. No biochemical tests were available for the comparison children. On admission the index children showed other signs of malnutrition not seen in the comparison children. Some degree of oedema, ranging from mild to severe, was present in all the index children, and skin changes were observed in 87% of the cases.

Psychological Examinations (1970-1971)

A broad spectrum of indicators of mental development was examined, including general reasoning, verbal-educational abilities, spatial-perceptual abilities, memory, and learning. The following tests were used:

1. Board form of coloured progressive matrices (21)
2. Luganda vocabulary especially contructed for this purpose
3. Arithmetic test adapted from the WISC (27)
4. Shortened version of the Porteus mazes (1)
5. Memory-for-designs test (13)
6. Memory-for-designs test (13)
7. Knox cubes (1)
8. Rote-learning test in which associations had to be memorized
9. Incidental learning on the previous test.

A detailed description of the tests, their construction, adaptation, reliabiltiy, and validity can be found elsewhere (15).

In the presentation of Knox cubes two speeds, normal and quick, were used following a suggestion by Klein (17). Since the normal and quick versions produced similar results and since no other indications were found that the two versions assessed different abilities a combination of the two scores is used throughout.

Table 2. Condition of index children at admission (N= 60).

Medical Indicators at Admission	Mean	Standard deviation
Percentage of expected weight for age[a,b]	69.7%	9.7
Percentage of weight lost after admission	8.4%	6.1
Haemoglobin level[b]	6.7g	2.1
Serum protein level	4.2g	0.7
Oedema[d]	3.8	0.8
Skin changes[e]	2.7	1.0
Overall clinical severity[c,d]	3.3	0.9

[a] Baganda standards (10,26).
[b] lowest level during hospitalization.
[c] as judged by the attending doctor.
[d] rated on ordinal scale from 1 to 5 (severe).
[e] rated on ordinal scale from 1 to 4 (severe).

The psychological examination took place near the child's home in a converted VW bus. All tests were given individually and did not rely on written instructions or questions. They were all conducted in the child's own language, Luganda, with the help of a female interpreter. Because African children are particularly at a disadvantage with speed tests, speed bonusses were abolished for all tests and time limits doubled.

Reliability estimates of the individual tests fall between .80 and .90 except for vocabulary (between .70 and .80), and Porteus mazes and incidental learning (both between .50 and .60). Factor analysis of the tests revealed three principal dimensions. The first dimension represents general reasoning and education. It is predominantly loaded by Raven matrices, vocabulary and arithmetic. The second, spatial-perceptual dimension, is identified mainly by block design and Porteus mazes, while memory-for-designs also loads on this component. The third component consists primarily of the memory and learning tests.

Additional Examinations.

In addition to the psychological tests various other examinations were carried out. These included:

1. A clinical medical examination
2. An anthropometric assessment.

The findings from these examinations have been presented elsewhere (4,5,16).

RESULTS

Malnourished vs. Comparison Children:

The mean test scores for the four groups under study are presented in Table 3. The three groups of malnourished children scored significantly lower on the Raven matrices, block design, memory-for-designs, and incidental learning (Table 4).

The memory-for-designs test has a skewed distribution of scores and the scores were dichotomized for purposes of correlational analysis. An error score of 5 or higher was recorded as 0, and a score of 4 or lower, as 1. Furthermore, wherever analysis of variance was used, Wilcoxon's signed ranks tests for matched pairs was utilized for this test.

Many studies have reported that the intellectual abilities of previously malnourished children are affected, including studies which have seriously attempted to eliminate the influence of external variables (2,3, 8,14,17,19). Two studies report contrary findings. The first found differences in IQ between malnourished children and matched controls, differences that were not significant although they were of a magnitude similar to those found in other studies (12). Evans, Moodie and Hansen (11) failed to find differences in IQ between formerly malnourished children and their siblings. The general picture is that malnourished children show impairment.

None of these investigations studies adults and the possibility remains that the malnourished children can still catch up by one or both of the twin processes of accelerated development or delayed maturation allowing for a longer period of development in the malnourished children. If catch-up occurs among the malnourished children, this means that over the years their test scores should improve more than that of better nourished children. This should be reflected in a higher correlation between age and test scores among the malnourished children. Because education will also influence test performance, partial correlations, independent of education, were calculated (Table 5). The partial correlations of age with test scores are neither positive nor significant, with a mean of -.12 among the malnourished children and -.08 in the comparison group, excepting the correlation between vocabulary and age which is positive as well as higher among the malnourished children. On the whole this evidence does not support the idea of a diminishing deficit. With the exception of the mastery of Luganda, both groups of children have reached their full mental development and the deficits of the malnourished children are likely to be permanent.

Table 3. Mean test scores for malnourished children and comparison group.

Group Number / Test	1 Age 8-15 months	2 Age 16-21 months	3 Age 22-27 months	4 Comparison Group
Raven matrices	22.8	21.9	21.5	24.1
Vocabulary	7.2	8.6	8.7	9.0
Arithmetic	8.8	9.7	9.6	9.3
Porteus mazes	6.4	6.3	6.2	7.0
Block design	16.7	15.7	16.4	21.9
Memory-for-design (errors)	7.1	8.7	4.4	4.7
Knox cubes	37.5	38.7	40.7	39.6
Learning	3.8	4.5	4.8	5.1
Incidental learning	4.0	5.1	4.6	5.9

Table 4. Analysis of variance: randomized block design (df = 1,57). F-values resulting from comparison of group 4 (comparison children) with groups 1, 2, and 3 (malnourished children).

TEST	F-VALUES % VARIANCE
Raven matrices	F = 4.24*
Vocabulary	F = 0.78
Arithmetic	F = 0.03
Porteus mazes	F = 2.66
Block design	F = 8.28**
Memory for designs	T = 48.5*[a]
Knox cubes	F = 0.18
Learning	F = 1.17
Incidental learning	F = 5.94*

[a]Wilcoxon matched-pair signed-ranks test.
*$p < .05$
**$p < .01$

Table 5. Partial correlations of age with test scores (education constant).

TESTS	MALNOURISHED GROUP (N = 3 x 20)*	COMPARISON GROUP (N = 20)
Raven matrices	-.14	-.01
Vocabulary	.46**	.25
Arithmetic	-.17	-.15
Porteus mazes	-.08	-.10
Block design	-.28	-.10
Memory for designs	-.11	-.19
Knox cubes	-.09	.07
Learning	-.03	-.17
Incidental learning	-.08	.05

*pooled results
**$p < .01$

Malnourished Children: Age at Hospitalization

The idea that a critical period in brain development exists not only in animals but also in man has given rise to the hypothesis that the younger the child when energy-protein malnutrition occurs, the more severe the ultimate effect. Findings from an early study by Cravioto and Robles (9) seemed to support this idea. Other studies, however, have failed to find a relation between the age at which malnutrition occurs and later intellectual abilities (7,14,19,22). One study which compared children hospitalized for malnutrition between 10 and 15 months of age with children admitted between 16 and 48 months, in fact, reported the opposite. When tested after the age of 9 years, the groups which had suffered earlier in life did considerably better than the group which had been admitted later in life (11).

All malnourished children in the present study had been admitted before the age of 28 months. Analysis of variance shows that there are no significant differences between the children admitted before 16 months of age and the children admitted at later ages (Table 6). In regard to the four tests which showed significant differences between the malnourished and comparison children, the group admitted at the younger age scored slightly higher on Raven matrices and block design, but slightly lower on memory-for-designs and incidental learning than the children admitted at later ages.

In the studies discussed above, the children were usually older than 6 months on admission. This is conceivably past the age of greatest vulnerability. Chase and Martin (8) compared nine children who were admitted for malnutrition before 4 months of age, with ten children who were admitted between the ages of 5 and 12 months. These groups were identical in their social background. At the age of 3½-4½ years, the groups which had suffered early were only slightly behind a matched control group of normal children in development. Contrary to what might be expected, the group of children admitted late, between 5 and 12 months, scored far below the group which was admitted early, and below the comparison group.

There is almost no convincing evidence that malnutrition occurring after 6 months of age, or even after 12-18 months of age, is less damaging than earlier malnutrition. However, we face a fundamental problem of interpretation. The age of the child at first treatment is usually taken to be synonymous with the age at onset of malnutrition. This seems justified with regard to acute malnutrition since the time elapsed between onset and first treatment will be short. The age at first treatment, however, does not correspond to the onset of chronic undernutrition, which may antedate the admission by varying amounts of time. In the next section we shall take a closer look at these two aspects of malnutrition.

Table 6. Analysis of variance: randomized block design (df = 1,57). F-values resulting from comparison of groups 2 and 3 (late admissions) with group 1 (early admissions).

TEST	F-VALUES
Raven matrices	F = 1.10
Vocabulary	F = 2.44
Arithmetic	F = 2.33
Porteus mazes	F = 0.14
Block design	F = 0.10
Memory for designs	T = 74.5[a]
Knox cubes	F = 1.96
Learning	F = 1.35
Incidental learning	F = 2.53

[a]Wilcoxon matched-pairs signed ranks test, n.s.

Dimensions of Malnutrition: Acute vs. Chronic

As noted before, from the data in the admission records seven indicators of the condition of each child were selected: weight, weight loss after admission, hemoglobin and serum protein level, and the degrees of oedema, skin changes, and over-all clinical severity as rated at the time of admission by the attending physician. The correlations between these seven indicators were computed for each of the malnourished groups and the three resulting correlation matrices were pooled into one matrix subjected to principal component analysis in order to obtain as systematic and economic a description of observed data as possible. This analysis yielded two independent dimensions of malnutrition (Table 7) which, to a greater or lesser extent, were present in each child. The first dimension is composed of those variables which are predominant in kwashiorkor, i.e., metabolic abnormality (low serum-protein levels giving rise to oedema and initial weight-loss during treatment after admission), skin changes and the doctor's judgment of severity of the condition on admission.

The dominant element in the second dimension is the weight deficit characteristic of marasmus, with stunting of somatic growth. Haemoglobin deficit also is an important element in this component.

We have called these components "acute malnutrition" and "chronic undernutrition," respectively. Together they determine the type of clinical malnutrition a child exhibits. Kwashiorkor and marasmus are used clinically as diagnostic terms for the total syndrome, and it would be confusing to apply them to its component parts. Furthermore, the variables in each of the two dimensions tend to evolve over different periods of time. The first dimension reflects acute changes, usually developing over a short time and precipitating admission to hospital. The second, consisting of weight deficit and haemoglobin deficit, usually develops over a longer period and thus reflects the chronicity of

Table 7. Medical indicators at admission: varimax rotation of first two principal components (malnourished groups pooled; N = 3 x 20).

MEDICAL INDICATORS AT ADMISSION	DIMENSION 1	DIMENSION 2
% of expected weight for age[a,b]	.07	-.80
% of weight lost after admission	.58	-.55
Haemoglobin level[b]	-.28	-.66
Serum protein level	-.59	-.10
Oedema	.73	-.17
Skin changes	.69	.00
Overall clinical severity[c]	.73	.23

[a]Baganda standards (10,26).
[b]lowest level during hospitalization.
[c]as judged by the attending doctor.

the malnutrition. Initial loss of weight during early treatment is characteristic of the acute condition. In contrast, the smaller the weight loss the more severe is the chronic condition.

For each child the severity of acute malnutrition and chronic undernutrition was computed as a weighted index, with a standard deviation of 1.0, based on the original seven variables.

The correlations between the magnitude of these two components of malnutrition as observed early in life and the test scores obtained more than 10 years later are presented in Table 8. Acute malnutrition shows no consistent correlations with the tests. Five of the nine correlations do not exceed ±0.06, while four of the correlations are positive and five are negative. The correlations of chronic undernutrition with the tests are consistently negative; that is, the children do less well on the tests the greater the degree of chronic undernutrition in early childhood. For five of the tests the correlations are significant; and although not significant for vocabulary, Porteus mazes, and learning, they are still negative and larger than 0.15.

Table 8. Correlations of two independent dimensions of malnutrition, acute malnutrition and chronic undernutrition, with tests (results of malnourished groups pooled; N = 3 x 20).

TEST	ACUTE MALNUTRITION	CHRONIC MALNUTRITION
Raven matrices	.02	-.40*
Vocabulary	-.12	-.17
Arithmetic	-.05	-.44*
Porteus mazes	-.06	-.18
Block design	-.02	-.34*
Memory-for-designs	-.02	-.33*
Knox cubes	.17	-.27**
Learning	.13	-.21
Incidental learning	.13	-.03

*$p < .01$, one-tailed test.
**$p < .05$, one-tailed test.

Other studies have also reported a relation between the degree of wasting or chronic undernutrition, and test performance (5,7,17). As previously discussed, Chase and Martin (8) found that children who had been admitted between 5 and 12 months of age showed much greater retardation than children who had been admitted before 4 months of age. The authors attribute this to the longer duration of chronic undernutrition in the older children, assuming that the malnutrition commenced shortly after birth. These studies, however, did not exclude the possibility of the acute episode also having an effect. The results of the present study indicate that chronic undernutrition is the factor responsible for lowered intellectual abilities later in life and not acute malnutrition, which shows no evidence of having an impairing effect. This offers an explanation why in one important study no differences in test performance were found between formerly malnourished children and their siblings when they were between 8 and 15 years of age (11). Siblings share the same environment and presumably experience similar nutritional circumstances. In fact, in this particular study the comparison group of siblings was also not different in respect to somatic growth. Apparently these children, although having escaped an episode of acute malnutrition, had suffered similar degrees of chronic undernutrition and were therefore equally intellectually affected.

CONCLUSION

The present study has explored the relation between malnutrition and intellectual abilities in two ways: first, by comparison with a matched group of children who were not severely malnourished during the first years of life; and second, by relating present intellectual abilities to the condition of each child on admission to the hospital.

The previously malnourished children show signs of (permanent) impairment when compared, at the ages of 11-17 years, with children of the same sex, age, and education coming from a comparable environment. Since the pattern of malnutrition occurring in Buganda is rather uniform (weight deficit together with frequent infections commences at the time of weaning, usually between 6 and 12 months of age), it follows that the child is still vulnerable at weaning. The impairment exhibited by the previously malnourished children shows a strong relation with an index, composed of weighted medical indicators, measuring the degree of chronic undernutrition at admission. No such relation exists with a similar index assessing the degree of acute malnutrition or metabolic imbalance at admission. This fits in with the finding that the impairment is independent of the age at which the children were admitted to the hospital.

The limitations of this study are that certain information, such as height, was not recorded at admission and that no systematic observations were made of these children prior and after their episode of malnutrition. On the one hand this reflects the limited knowledge about the condition at the time. On the other hand, it is through the foresight of Dr. Dean, the late director of this unit, that systematic observations were recorded and carefully kept from 1954 onwards. The combination of data in admission records with later test performance has enabled us to identify chronic undernutrition as the damaging process.

Chronic undernutrition has two components, the degree of faltering and the duration of such faltering. There is little evidence that one of these two is the more important. Furthermore, in retrospective studies it is usually not possible to distinguish between the respective contributions of these two aspects of the final condition of the child. The lack of positive findings among children in Western countries who for strictly medical reasons become malnourished suggests that duration is important (18,24). After the age of 5 years these children showed no difference in test performance when compared with their siblings. Although both studies have certain weaknesses they recall similar findings in a study (8) where no effects were observed among children who had been malnourished before the age of 4 months. This suggests that children who become severely malnourished early in life suffer relatively little damage as regards their later intellectual abilities. This could be explained by a greater plasticity of the infantile nervous system during the early months of life. It is also possible that in very young children malnutrition simply has not lasted long enough to have measurable long-term effects. Another possible explanation is that malnutrition impairs intellectual abilities by way of experiential deprivation, which possibly becomes important only after 6 months of age.

Whatever the answers to these last questions, two inferences can be drawn. First, since chronic undernutrition plays the crucial role, treatment of acute cases is insufficient to prevent intellectual impairment. Secondly, the intellectual abilities of children who suffer from chronic undernutrition but who never experience an acute episode, a far more numerous group, are likely to be similarly impaired.

SUMMARY

Three groups of Ugandan children (20 in each group) and one comparison group of 20 children were examined between 11 and 17 years of age. The children in the first three groups had suffered from energy-protein malnutrition 10 to 16 years previously when they were hospitalized at different ages (between 8-15 months, 16-21 months, and 22-27 months). The comparison group consists of of children who had not suffered from clinical malnutrition during infancy. All the children came from one tribe and were individually matched for sex, age, education and home environment.

The three groups malnourished in infancy fell significantly below the comparison group in test performance at the later age. Further analysis showed that the deficit is not related to the severity of acute malnutrition, but rather to the degree of chronic undernutrition at admission. No evidence was found for a relationship between impairment and the age at admission.

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